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# Breakage Susceptibility of Blended Corn

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## ABSTRACT

A test of the breakage susceptibility of blended corn was conducted with four moisture levels of dry corn (8, 9, 11, and 8.9% desiccant) blended with 24.4% moisture corn to two theoretical moisture levels (15.5 and 20%). The study showed that blending wet and dry corn increases the Stein breakage 0.74 to 4.47 points for a 15.5% blend and 1.54 to 10.6 points for a 20% moisture blend. The breakage in local handling due to blending wet and dry corn is likely to be from 0.1 to 1.7%, which will probably not result in a discount at the time of sale.

## INTRODUCTION

Using overdry corn from a solar grain-drying system as a desiccant for blending with wet corn at harvest prolongs the use period of a solar collector and saves energy. In the desiccant system described by Bern et al. (1981), corn from the previous harvest is overdried during spring and summer with heat from a solar collector. In the fall, part of the overdried corn is blended with wet, freshly harvested corn to produce a 20% moisture content blend, which is then low-temperature dried to a safe storage moisture content. The rest of the desiccant is blended with wet corn to produce a 15.5% moisture content blend for sale or storage. The cycle from 24%, to under 10%, to 15.5% or 20% moisture may increase kernel susceptibility to breakage and lead to a discount at the time of marketing. Also, farmers often blend dry corn with a moisture content less than 15.5% with wetter corn to obtain a 15.5% moisture blend for marketing. The effect of blending corn on breakage susceptibility has not been studied thoroughly. This research was undertaken to help quantify such effects.

## OBJECTIVES

The objectives of this research are:

1. To determine the breakage susceptibility of blended wet and dry shelled corn.
2. To examine the moisture contents of wet and dry portions after blending and storage.
3. To evaluate economic aspects of increased breakage caused by blending.

## REVIEW OF LITERATURE

### Stress Cracks

Thompson and Foster (1963), studied stress cracks and breakage in artificially dried corn and found that shelled corn dried with heated air was two to three times

more susceptible to breakage than the same corn dried with unheated air. They also observed that corn dried from 30% moisture to 15.5% was more susceptible to breakage than that dried from 20%. As the drying air temperature and air-flow rate were increased, the shelled corn became somewhat more susceptible to breakage.

Hart (1967) found that when overdried corn was mixed with undried corn to produce a mean moisture content of 15.5%, the mixture was more likely to become moldy than unmixed samples at the same moisture level. The moisture of neither fraction reached the average moisture content, but the moisture of the mixture remained nearly constant from the third day.

Brekke (1968) studied stress crack formation caused by rewetting low-moisture corn. Corn with initial moisture contents from 10% to 20% was rewet at 24 °C. Rewetting corn with an initial moisture content of 20.1% produced no stress cracks in a 6-h period. For 14.6% corn, almost 50% of the kernels developed stress cracks in 2 h. The rate of stress crack formation showed further increases as initial moisture of corn was lowered to 10.1%. When 13.4% moisture corn was rewet at 24 °C to moisture levels of 15, 16, 18, and 21%, no stress cracks developed at 15% moisture, but stress cracking increased as moisture levels were progressively raised to 21%. For 21% moisture, approximately 60% of the kernels had stress cracks after 2 h.

White et al. (1972) blended dry corn at 8% and wet corn at 23% moisture. The mixtures were held for 8 days at temperatures from 4 and 38 °C without aeration or further disturbance. The moisture content of the mixture did not change from the third day, and the moisture difference between the two fractions never became less than 1.7 to 3.4 points.

### Breakage susceptibility

Stephens and Foster (1976) conducted a series of tests to determine the relationship between breakage in a Stein breakage tester and actual breakage due to handling. They used three different batches of corn. Two batches had been dried in a bin with unheated air. The third batch was obtained from commercial stocks. Corn was removed from a storage bin, elevated 48 m by bucket elevator and dropped through a spout into a truck. Breakage due to handling was determined by sampling before and after handling. Samples taken before handling were evaluated in a Stein breakage tester for 4 min. Sample moisture contents ranged from 10.8 to 13.5%. They found the ratio between Stein breakage and actual breakage due to this handling to be about 6.3 to 1.

Herum and Hamdy (1981) evaluated the ability of several breakage testers to predict corn breakage resulting from passage through a full-scale grain elevator. This elevator was considered to be representative of small commercial elevators. Shelled corn was cycled through the elevator eight times. In each

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pass, the corn was taken from a 213-m<sup>3</sup> hopper-bottomed tank, carried laterally in a U-tube auger, lifted 22.9 m in a bucket elevator, passed through a separator, gravity fed into a shorter bucket elevator and finally dropped into another 213-m<sup>3</sup> tank. Samples were withdrawn after each pass to evaluate possible changes in breakage susceptibility due to handling. Breakage susceptibility was measured with three testers: Stein CK-2M (4 min. test duration), a modified Stein, and a centrifugal impact tester. They found the ratio between average breakage for all three testers and actual breakage due to handling to be about 10 to 1.

#### Economic aspects

Bern et al. (1981) found that, in comparison field tests, a system employing overdried corn as a desiccant for mixing with wet corn used 31% as much electrical energy as a conventional low-temperature drying system. They also found total drying costs for the desiccant system to be about the same as costs for a conventional low-temperature system. In their analysis, possible discounts due to corn breakage were not considered.

Hurburgh (1981) reported that the typical discount for broken corn and foreign material (BCFM) at country elevators is 2¢ per bushel for each point over 3%.

### PROCEDURE

#### Experimental design

This experiment was designed to determine the breakage susceptibility and moisture content of blended corn and the wet and dry portions after a storage period.

The experiment included the following treatments: (a) a control sample (three replications); and (b) four levels of dry corn (8, 9, 11%, and 8.9% moisture desiccant) blended with 24.4% corn to two theoretical moisture levels (15.5% and 20%). The dry corn moisture contents represent practical limits of desiccant product—under 8% moisture requires too large a collector, over 11% moisture requires too much desiccant. The 15.5% moisture blend was selected because it is the maximum moisture content for No. 2 grade yellow corn. The 20% moisture blend was selected because it is suitable for safe, low cost, low-temperature drying (Bern et al., 1981).

With 4 dry corn moisture levels and 2 blended levels, eight experimental units were produced. Each unit was replicated three times, making 24 replications. Each replicate was separated into wet corn, dry corn, and blended corn, giving 72 samples. When the 3 control replicates are added, there are a total of 75 moisture content determinations and 75 breakage tests.

#### Grain

Ears of 25% moisture yellow dent corn (Pioneer 3780) were picked by hand at the Agronomy-Agricultural Engineering Research Center located west of Ames, IA, in the fall of 1980. The corn was shelled with an International Harvester electric motor-driven sheller and cleaned with a Carter Dockage Tester. Whole kernels passing through 6.35-mm round hole sieve were picked by hand and used as test grain. About 20 kg of corn was used in the experiments.

All moisture contents in this report are wet basis and were determined by use of the 72-h, 103 °C air-oven procedure (Agr. Engr. Yearbook, 1981).

#### Wet portion

Eight kg of 24.4% wet corn used in the blending experiments was dyed with 0.2% Fast green FCF dye. The dye colored the kernel tips blue and allowed identification of the wet portion of blends. Dying the corn did not change the moisture content.

#### Dry portion

Three 3-kg lots of dry corn were prepared by drying wet corn to 11%, 9%, and 8% with room air heated to 24 °C.

Three 1-kg corn lots of wet corn were dried with room air to 12.8 ± 0.2% for use as control samples. This moisture was recommended by NC-151 collaborative study for conducting Stein breakage tests (Miller et al., 1980).

#### Desiccant corn

As a comparison with laboratory - prepared samples, corn of unknown variety was collected from a bin of desiccant corn located at the Iowa State University Woodruff Farm, southwest of Ames. This corn had been dried over summer 1980 with heat from a solar collector and was destined for use as a desiccant to be mixed with wet harvest corn. Its moisture content was 8.9%. Enough whole kernels were picked by hand to provide a 3-kg sample of desiccant.

#### Blending of grain

Wet and dry portions were blended to obtain the final theoretical moisture contents of 15.5% and 20%. The required weight of each portion was calculated using the equation:

$$M_F (x + y) = M_d(y) + M_w(x)$$

where:

- $M_F$  = final theoretical moisture content of blended portion, wet basis, decimal
- $x$  = weight of wet portion, g
- $y$  = weight of dry portion, g
- $M_d$  = moisture content of dry portion, wet basis, decimal
- $M_w$  = moisture content of wet portion, wet basis, decimal.

The quantity of wet and dry portions needed was determined by measurements to be taken after blending and by the volume of the storage jar. For this experiment, 15 g was required for moisture measurement and 180 g for breakage tests. Thus, samples needed to be at least 195 g total.

The dry and wet portions were blended using a Boerner divider. Four lots of three samples each of wet and dry portion were blended to a theoretical moisture content of 15.5% and another four lots were blended to 20% moisture. These samples were held in 2-L jars and stored at 20 °C one day and then three days at 2 °C. During storage, samples were mixed three times per day by turning the jars upside down five times.

After four days, samples were hand separated into dry, wet and blended portions. These portions were kept in separate sealed jars and held three days in the cold room while awaiting moisture determination.

After moisture determination, the samples were conditioned to 12.8 ± 0.2% moisture with room air at 20

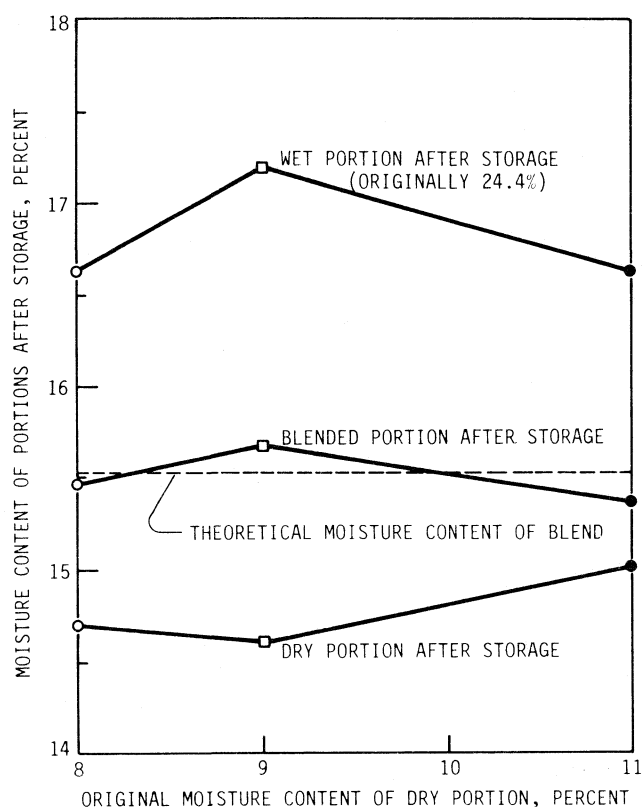


Fig. 1—Moisture content of portions after 4 days in storage vs. original moisture content of dry portion (15.5% theoretical moisture blend).

°C and held at 2 °C for two days to equalize moisture before breakage testing.

#### Stein breakage tester

A Stein CK-2M breakage tester was used in this experiment. Sample size for all breakage tests was  $100.0 \pm 0.1$  g. Samples were placed in the tester for 4 min. (Miller et al., 1980). Fines passing a 4.76-mm roundhole sieve were weighed, and percent breakage was calculated:

$$\text{Percent breakage} = \frac{\text{weight of fines}}{\text{weight of sample}} \times 100$$

## RESULTS AND DISCUSSION

### Moisture content after storage

Figs. 1 and 2 show the moisture content of wet and dry portions of corn after being stored for a day at 20 °C and then 3 days at 2 °C. The moisture content of the two portions never reached the theoretical moisture content of the blend. The difference in moisture contents between the wet and dry portions ranged from 1.52 to 2.61 points for the 15.5% theoretical moisture blend and from 1.07 to 1.52 points for the 20% theoretical moisture blend.

The average difference in moisture content between the 8.9% desiccant and wet portions was 2.57 points for 15.5% and 1.52 points for 20% theoretical moisture blend. These differences were higher than when the wet and dry portions were of the same corn variety.

The residual difference in moisture contents between wet and dry portions after blending may be caused by the same factors that cause hysteresis in the equilibrium moisture content curves. Exposed to the same temperature and relative humidity, wet and dry corn do

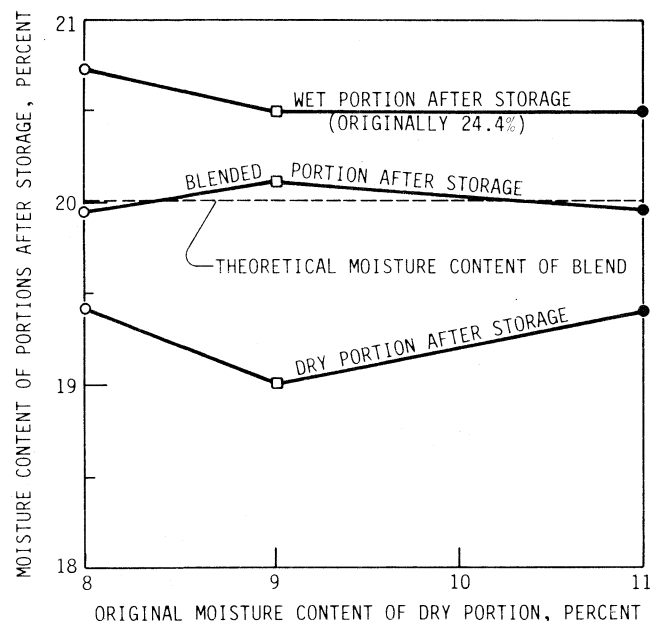


Fig. 2—Moisture content of portions after 4 days in storage vs. original moisture content of dry portion (20% theoretical moisture blend).

not come to the same moisture content. The dry portion follows the adsorption curve and wet portion follows the desorption curve (Chung and Pfost, 1967).

### Susceptibility to breakage

Figs. 3 and 4 show breakage of dry, wet and blended portions. Average breakage for the control lot was 6.13%.

The breakage of a blend of 24.4% corn with dry corn at 8, 9, and 11% moisture to 15.5% moisture was 9.43%, 8.10% and 6.87% respectively. This indicates that the lower the moisture content of dry portion, the higher the susceptibility of the blend to breakage.

The breakage of a blend of 24.4% corn and desiccant at 8.9% moisture was 10.60%, which was higher than the other samples. The increased breakage susceptibility may have been caused by machine harvest and additional

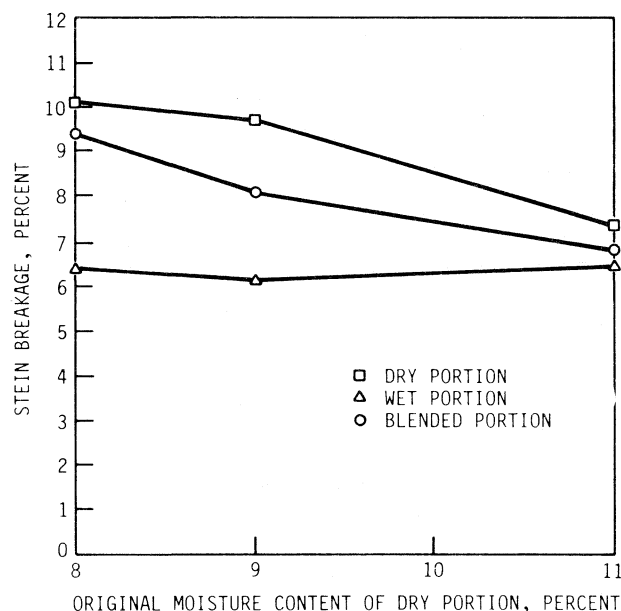


Fig. 3—Kernel breakage as affected by moisture content of dry portion (15.5% theoretical moisture blend).

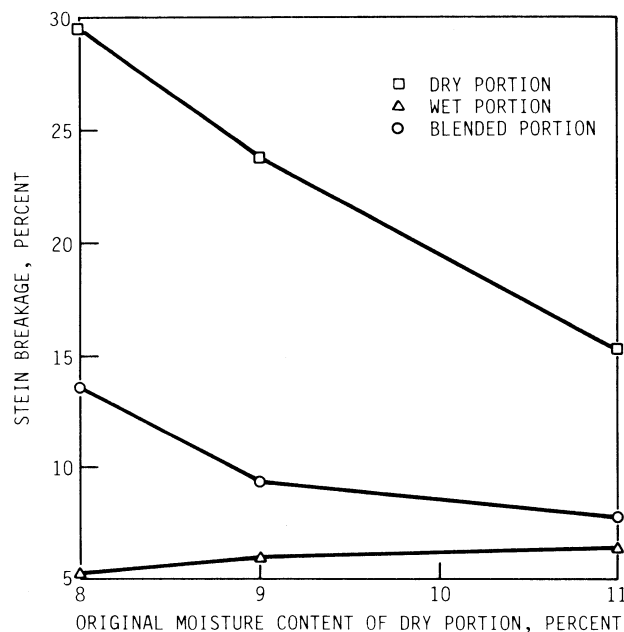


Fig. 4—Kernel breakage as affected by moisture content of dry portion (20% theoretical moisture blend).

mechanical handling of the desiccant.

The breakage of a blend of 24.4% corn with dry corn at 8, 9, and 11% moisture to 20% moisture was 13.53%, 9.27%, and 7.67%, respectively. The breakage of a blend of 24.4% corn and desiccant at 8.9% moisture was 16.73%. Again, the indication is that the lower the moisture content of the dry portion, the greater the breakage susceptibility of the blend.

The difference between breakage of the 15.5% moisture blend and control breakage ranged from 0.74 to 4.47 points, and the difference between breakage of the 20% moisture blend and control breakage ranged from 1.54 to 10.60 points. Therefore, blending wet and dry corn to 15.5% results in less breakage than blending to 20% moisture. All the extra breakage for the 20% blend is in the dry portion. Drying corn from 24.4% to 11% or less and then rewetting it to 20% probably stresses kernels more than drying to 11% or less and then rewetting to only 15.5%.

For 20% moisture blends, the breakage of dry portions ranged from 15.36 to 43.33%. Breakage of wet portions ranged from 5.23 to 7.17%, and breakage of blended portions ranged from 7.67 to 16.73%. Breakage of blended samples was not proportional to the ratio of blending of wet and dry portions. It may be that the wet kernels act as a cushion in the blend and reduces breakage of the dry portion during breakage tests.

### Selecting the blending ratio

The breakage susceptibility of blended corn changed with the moisture content of the dry portion and the moisture content to which the corn was blended. A statistical analysis was performed comparing breakage at different dry portion moisture contents within the same level of blended moisture and the breakage at different levels of blended moisture at the same level moisture of dry portion (Steel and Torrie, 1980).

#### For blending wet corn and dry corn

The analysis of variance indicated that:

1. Differences in breakage between 8 and 9%, and 9 and 11% moisture dry portions for 15.5% moisture

blend are not significantly different, but the difference between 8 and 11% is significantly different at the 95% confidence level.

2. Differences in breakage between 8 and 9%, 9 and 11%, and 8 and 11% moisture dry portions for a 20% moisture blend are significantly different at the 95% confidence level.

3. Differences in breakage between the two levels of blended moisture at 9 and 11% moisture dry portions are not significantly different, but the difference is significant for an 8% moisture dry portion at the 95% confidence level.

#### For blending wet corn and desiccant

The analysis of variance showed that the breakage of 15.5% and 20% moisture blends is significantly different at the 95% confidence level.

From the above analysis, we can draw the following conclusions:

1. The differences in breakage between 15.5% and 20% blends of 24.4% corn with 9 or 11% moisture dry corn are not significant.

2. For 15.5% moisture blend, blending 24.4% corn with dry corn at 11% moisture will have the least breakage. However, the blending ratio is more favorable for dryer corn, which means that given the same amount of dry corn, we can blend a larger amount of wet corn. But the lower moisture content of the dry corn also means that the drying time must be longer and more energy is used for drying.

### Economic aspects of blending

In the grain trade, corn which has a BCFM level less than 3% is not usually subject to discount. Unpublished results from three years of tests at Iowa State University indicated a BCFM level of about 1% for low-temperature drying (G. L. Kline, Agric. Engr. Dept., Iowa State Univ., 1981, personal communication). This BCFM level included harvest, handling, and drying damage. The percent breakage added between the drying bin and final destination is unknown. We can predict the breakage that will occur at the elevator after on-farm blending if we assume the handling system and corn used by Stephens and Foster (1976) are representative.

This study found the difference in breakage between control samples and 24.4% corn blended with 8, 9, 11, and 8.9% moisture dry portions to 15.5% moisture to be 3.30, 1.97, 0.74, and 4.47% respectively. Using Stephens and Foster's ratio of 6.30 to 1, actual breakage should be 0.52, 0.31, 0.12, and 0.71%. The actual BCFM in this system can be assumed to be the sum of normal BCFM of the conventional low temperature system (1%) plus the 0.52, 0.31, 0.12 and 0.71% due to handling. The predicted totals of 1.52, 1.31, 1.12 and 1.71% BCFM for 8, 9, 11, and 8.9% moisture desiccant, respectively, should not result in any discount at the time of sale by the producer.

This study found the difference in breakage between control samples and 8, 9, 11, and 8.9% moisture corn blended with 24.4% corn to 20% moisture to be 7.40, 3.14, 1.54, and 10.60% respectively. Again, using the ratio of 6.30 to 1, actual breakage should be 1.17, 0.50, 0.24, and 1.68%. Total BCFM due to drying and handling after blending would be 2.17, 1.50, 1.24, and 2.68% BCFM for 8, 9, 11, and 8.9% moisture desiccant, respectively. These breakage levels are not likely to result

in any discount at the time of sale by the producer.

### SUMMARY

Wet corn from the field, dried in the laboratory by room air to 8, 9, and 11%, and 8.9% moisture desiccant corn from a solar drying bin was blended with wet corn at 24.4% moisture content to produce blends of 15.5 and 20% moisture. The wet corn was dyed for identification and after 4 days storage, the samples were separated into the original portions.

The moisture content difference between the dry and wet portions of blended corn ranged from 1.51 to 2.75% for the 15.5% moisture blend and from 1.02 to 1.54% for the 20% moisture blend. The moisture content difference between the wet portion and the dry portion was smallest when 11% moisture dry corn was used. The highest difference between wet portion and dry portion occurred when 9% moisture dry corn was used for both 15.5% and 20% moisture blend.

Stein breakage susceptibility of blended corn ranged from 6.87 to 10.60% for a 15.5% moisture blend and from 7.67 to 16.73% for a 20% moisture blend. Breakage of blended corn increased with decreasing moisture content of the dry portion (11, 9 and 8% moisture) for both 15.5% and 20% moisture blends. Breakage was highest for both 15.5% and 20% moisture blends when solar-dried desiccant was used as the dry portion.

Blending wet and dry corn increases breakage susceptibility but probably not enough to result in a discount at the time of first sale.

### CONCLUSIONS

The following conclusions can be drawn from this study.

1. The moisture content of wet and dry portions in the blend do not equalize in 4 days in storage.

2. The breakage susceptibility of blends of wet and dry corn increases with a decrease in moisture content of the dry portion, and this breakage susceptibility is higher for a 20% moisture blend than for a 15.5% moisture blend.

3. Blending of wet and dry corn is not likely to result in BCFM discount at the time of first sale.

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